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ABSTRACT

The central premise of this study was that the use of graphing calculator technology helped improve students' achievement in upper level biology courses. The populations studied included high school students in a block course entitled "AP Biology/AP Calculus" and students in a traditional AP Biology course. There appears to be a positive effect on student understanding and achievement on standardized exams when the graphing calculator is regularly used in an integrated science/math course. Students enrolled in the integrated Advanced Placement Biology/Advanced Placement Calculus block course where graphing calculators were a meaningful part of the curriculum performed significantly better on the Advanced Placement Biology exam when compared to students enrolled in the traditional Advanced Placement Biology where graphing calculators were not heavily integrated into the course. There appears to be a positive correlation between integrating graphing calculators in the higher level biology classes and the understanding and achievement of the students enrolled in the integrated course. (ASK)

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Graphing Calculators' Impact on AP Biology

by
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The research is clear and consistent that the use of calculators in the mathematics classroom enhances the learning and understanding of mathematics. Likewise, educational researchers have long been touting the benefits of integrating multiple subject areas, such as science and mathematics, to bring greater meaning to each discipline. Because science is heavily reliant on mathematics and mathematics has become heavily reliant on technology, research indicates that science instruction can benefit from the integration of similar technology in the classroom.

The central premise of this study was that the use of graphing calculator technology helped improve students' achievement in upper level biology courses. The researcher was unable to find any studies devoted to graphing calculators' impact on biology, so there appears to be a void of study on this subject until now. The attempt of the research in this paper is to explore the question, and hence, start the discussion.

Theoretical Support

The National Council of Teachers of Mathematics (NCTM), in a position statement released in 1996, stated that, "Research and experience have clearly demonstrated the potential of calculators to enhance students' learning in mathematics. The cognitive gain in number sense, conceptual development, and visualization can empower and motivate students to engage in true mathematical problem solving at a level previously denied to all but the most talented. The calculator is an essential tool for all students in mathematics."

The NCTM Standards, also published in 1996, provided that, "Science requires the use of

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mathematics in the collection and treatment of data and in the reasoning used to develop concepts, laws, and theories. School science and mathematics programs should be coordinated so that students learn the necessary mathematical skills and concepts before and during their use in the science program."

Devitt (1997) believes that technology is one of the most effective means of getting students excited about science. Technology gives students the freedom and encouragement to think and act like real scientists. Modern science relies, to a tremendous degree, on technology to detect, measure, calculate, manipulate, visualize, and communicate the data that is the raw material of discovery. Molding data into images is what makes science come alive, according to Devitt. While the raw data are important, the pictures are what scientists use to arrive at conclusions and achieve new insights. In the realm of science education, Devitt claims, this is true as well.

Furthermore, Devitt continues, one of the key features of a scientist's job is to discover mathematical relationships between variables. The most effective way of accomplishing this is through graphing. When done in the classroom this allows science students to DO science, rather than merely providing steps to follow, as in a cookbook.

Oakes (1997) maintains that a sufficient level of expertise in graphing and determining the slope from a graph are essential elements to understanding science. However, the instructor cannot assure any such level of expertise in his or her students. The instructor must be ready either to teach proper graphing techniques or to prepare students to use appropriate graphing and data analysis software whether it be computers or graphing calculators. Graphing requires the use and understanding of mathematical relationships and patterns in order to explain scientific data. Computers and calculators allow learners to explore 'what ifs' in domains not normally accessible.

They also make generating and analyzing graphs much less frustrating and time-consuming.

Kennedy (1995) offers the view that the graphing calculator is actually a computer - a computer with a very focused mission, running sophisticated internal software that is devoted to mathematics. It does simple mathematics for those with simple tastes, and it does advanced mathematics for those with advanced tastes. Most significantly, it also performs advanced mathematics for those students with simple tastes.

Dunham (1994) seems to speak for all educators when she says that no one believes that simply carting a set of graphing calculators into a classroom will have some magical effect on students. However, graphing calculators make the power of computer visualization a reality for secondary and college students. They can store, manipulate, and display data in many different ways. In truth, calculators are nothing more than well-programmed, miniature computers.

Smith (1999) offers what appears to be a realistic concession by stating that in an era when technology has become a hallmark of societal needs, the question of whether or not children should be using calculators in math and science seems outdated. The recommendations of curriculum, instruction, and assessment reflect widespread support for the use of handheld technology in schools. The question, 'Should kids be using calculators?' has been replaced with, 'In what ways should kids be using calculators?'

Description of the Study

The population used in this study included high school students enrolled in a block course entitled "AP Biology/AP Calculus" and students in a traditional AP Biology course. The block course was designed to be a 2- period course that had the goal of integrating science and mathematics. The same teacher, the same curriculum, and the same amount of time during the course of the school year were devoted to the traditional AP Biology course and the AP Biology

block class.

Grade point averages at the researcher's high school are calculated on a 4.0 scale and all classes receive the same grade point value for the same letter grade. In other words, there is no weighting of grades for Advanced Placement courses. A statistical comparison of the grade point averages of students enrolled in the AP Biology/AP Calculus block class and the students enrolled in the separate AP Biology classes were compared. The cumulative mean GPA for students enrolled in the block class during the 1997-1999 school years was 3.78/4.0 (n=39), while the cumulative mean GPA for students enrolled in the traditional classes was 3.52/4.0 (n=105) for this same period of time. This represents a 7.4% higher GPA for the students in the block class compared to those in the traditional class during the entire two-year study period. The t-test for independent samples indicated a significant difference between the block class and separate classes. The t-value ($t=4.59$) was significant at the $p<.05$ level.

Students who register for the AP Biology/AP Calculus block course are together for two consecutive periods. The researcher and his colleague most often take one period apiece to teach their respective courses, but they frequently team-teach for the entire block of time. This has been valuable when doing a laboratory activity that would normally take more than the allotted 50 minutes of a "normal" class period. The block of time has also allowed the teachers to more fully examine the connections between Biology and Calculus. To do this, the teachers and students relied heavily on the technology of the graphing calculator and Calculator- Based Laboratory (CBL). The CBL is a data collection device which is used with a variety of "probes" designed to collect data on such factors as temperature, pH, air pressure, conductivity, and force. The CBL is interfaced with the graphing calculator, and the calculator is then used to display, manipulate, and analyze data. Students in the block class consistently and frequently implemented the graphing

calculator, while this same calculator was rarely used in the traditional AP Biology course.

In the researcher's school district, the national assessment given to the juniors during the Spring of the year is evidence of the emphasis put on analyzing, interpreting and understanding data. On the science portion of that assessment, 36 out of 40 questions include either a graph, a diagram, or a data set for the students to interpret. Virtually the entire second half of the multiple-choice section of the AP Biology Exam contains questions based on graphs, diagrams, or data sets.

In the view of the researcher, something significant has happened in the AP Biology/AP Calculus block class. Analysis, synthesis, and evaluation have become as natural as they are critical to truly understanding the biological sciences. Consistent use of the graphing calculator as a powerful analytical tool has helped the students in the block class achieve at a higher level than those students in the more traditional setting.

The instrument used in this study was the Biology Advanced Placement exam. The Advanced Placement exams are scored on a scale of 1 - 5, with 5 being the highest possible score on each exam. The majority of colleges and universities in the United States consider a score of 3 to be passing, and the student will earn college credit for a score of 3 or higher.

Findings of the Study

1. A statistical comparison of the AP Biology Exam scores of students enrolled in the AP Biology/AP Calculus block class where graphing calculators were an intricate part of the learning process and the students enrolled in the separate AP Biology classes where graphing calculators were used infrequently was conducted. The cumulative mean AP Biology Exam score for students enrolled in a block class where graphing calculators were consistently a part of instructing during the 1997-99 school years was 3.56 (n=39), while the mean AP score for students enrolled in the

traditional classes was 2.54 (n=105). This represents a 43.5% higher achievement on the Advanced Placement Biology Exam for the students in the block class using graphing calculators compared to those in the traditional classes during the entire two-year study period. The t-test for independent samples indicated a significant difference between the block class and the traditional classes. The t-value ($t=5.31$) was significant at the $p<.05$ level.

2. The percentage of students passing the AP Biology exam who were enrolled in the AP Biology/AP Calculus block class that consistently incorporated graphing calculators into the curriculum during the 1997-99 school years was 85% (n=39), while the percentage passing among the students in the traditional classes was 38% (n=105). A "passing" score on the Advanced Placement Biology Exam is considered to be 3 or higher on a scale of 1-5. Students enrolled in the block class using graphing calculators over the two-years of this study earned passing scores at a 47% higher rate than those students in the separate classes.

Conclusions

There appears to be a positive effect on student understanding and achievement on standardized exams when the graphing calculator is regularly used in an integrated science/math course. Students enrolled in the integrated Advanced Placement Biology/Advanced Placement Calculus block course where graphing calculators were a meaningful part of the curriculum performed significantly better on the Advanced Placement Biology exam when compared to students enrolled in the traditional Advanced Placement Biology where graphing calculators were not heavily integrated into the course. There appears to be a positive correlation between integrating graphing calculators in the higher level biology classes and the understanding and achievement of the students enrolled in the integrated course. In order to be more definitive, more

research needs to be done in this area.

During those times when the calculator was used in the Biology portion of the Block class, the students were comfortable and confident because of their frequent use of the calculator in the class. Analysis of graphical presentations of data was viewed by the student as natural, non-threatening, and expected. In the traditional AP Biology class, on the other hand, students viewed the use of the graphing calculator as an "add-on" to the course, and whenever the calculators were used, there was a need for the researcher to instruct students in their use and in their power to more fully analyze data.

Analyzing, interpreting, and understanding various forms of data representation have become the foundation of many district, state, and national assessment tools. It is apparent that writers of standardized exams are very interested in a student being able to extend beyond the level of basic knowledge to the levels of analysis, synthesis, and evaluation. Consistent use of the graphing calculator as a powerful analytical tool has helped the students in the block class achieve at a higher level than those students in the more traditional setting.

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